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EFFECT OF PHYTOHORMONES ON POTATO GROWTH AND THE SIZE OF THE STARCH GRANULES

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ZIKA (18) and MALCHER and ZIKA (11) found that treatment of potato seed pieces with indoleacetic acid resulted in an increased yield of tubers and in a considerably larger average size of the potato starch granules. Although there was a temporary inhibition of sprouting associated with the phytohormone treatment, growth during the vegetative period was vigorous and surpassed that of the control plants. In this country a number of phytohormones have been used to retard sprouting of stored potatoes (3, 4, 5, 7, 8, 9, 15), and data on the germination and growth of the treated tubers have been reported by GUTHRIE (9), DAINES and CAMPBELL (3), VAN DER WAAL (17), and PUJALS *et al.* (13). In general, the treated potatoes showed delayed germination, and the subsequent growth was inferior to that described by ZIKA (18), MALCHER and ZIKA (11), and TRNKA *et al.* (16). The former workers (3, 9, 13, 17), however, made no observations on the size of the starch granules.

We have attempted to duplicate ZIKA's (18) observations, using the Green Mountain variety of potatoes. Our principal interest was in the reported increase in the size of the starch granules of the offspring tubers and in determining whether increased size was accompanied by differences in starch composition and pasting properties. According to European potato starch standards, increased granule size would in itself improve the commercial quality of the starch (6).

Methods

Seed pieces of certified Green Mountain seed potatoes (*Solanum tuberosum* L.) were disinfected with 0.2 per cent. mercuric chloride. One lot was soaked for 26 hours in 63 p.p.m. of indoleacetic acid,[1] a second lot was soaked in 63 p.p.m. of indolebutyric acid and an untreated lot served as controls. A total of 1750 seed pieces were planted in appropriate replicates on the Laboratory grounds. Fertilizer (5–10–10) was applied as a band at the seed level at the rate of one ton per acre. The plants were sprayed periodically with Bordeaux mixture, calcium arsenate, and nicotine sulphate (10), but the effectiveness of the spray was much diminished by the frequent rains during the summer of 1945. When the tubers were sufficiently mature (15 weeks after planting), some were dug at weekly in-

[1] ZIKA (18) treated the variety Ackersegen with 63 p.p.m. of indoleacetic acid, and MALCHER and ZIKA (11) treated the varieties Parnassia, Robinia, and Rotschalige with 10, 63, and 125 p.p.m. of indoleacetic acid.

tervals for measurement of the starch granules. Since the weather was excessively wet and growth was relatively poor during the experiment, it was repeated (except for the harvesting of tubers at weekly intervals) on a small scale (16 seed pieces for each treatment) the following year. In this experiment, the control seed pieces were soaked in water for 24 hours.

For the extraction of starch, unpeeled tubers were disintegrated in a Waring Blendor. The resulting slurry was passed through a 100-mesh screen to remove coarse pieces of cork and then centrifuged. The supernatant layer, which microscopic examination showed was essentially free of starch, was decanted, and the settled layer (starch) was reslurried and recentrifuged. The starch was washed in this manner three times, then dried. Although the starch recovered was not of high purity, nearly all the original starch granules, except possibly some about a micron or less in diameter, were retained for the granule measurements.

The long axis of the granules was measured with a calibrated Whipple ocular micrometer at a magnification of 440 diameters. Estimates were made to 0.2 division of the Whipple disc, equivalent to 4.08 microns. Seven hundred to 1000 granules from each sample were measured. BARHAM *et al.* (1) have shown that measurement of 500 granules is sufficient to determine the granule size distribution in a starch sample.

Results

GERMINATION AND GROWTH

Treatment of seed pieces with indoleacetic acid and indolebutyric acid retarded the rate of emergence of sprouts above the ground (table I). This retardation occurred in both an unfavorable growing season (1945) and in a favorable season (1946). In the former season, the hormone treatments also reduced total germination. The rate of emergence of

TABLE I

EFFECT OF INDOLEACETIC ACID AND INDOLEBUTYRIC ACID ON THE RATE OF GERMINATION OF GREEN MOUNTAIN POTATOES

TREATMENT	PERCENTAGE EMERGENCE OF SPROUTS ABOVE GROUND								
	1945*				1946†				
	Days after Planting				Days after Planting				
	27	38	48	54	12	19	21	23	26
None	0	64	80	80	31	100	100	100	100
Indoleacetic acid (63 p.p.m.)	0	20	60	64	0	0	63	100	100
Indolebutyric acid (63 p.p.m.)	0	18	52	64	0	0	44	94	100

* Planted April 19.
† Planted May 15.

sprouts in all samples was comparatively slow during the unfavorable season.

The yield of tubers per plant at maturity was decreased by the hormone treatments in both seasons (table II). The yield of tubers from plants treated with indoleacetic acid was decreased 17 per cent. in 1945 and 24 per cent. in 1946. Most remarkable was the comparative increase in yield associated with the favorable growing season. For example, plants from seed treated with indoleacetic acid yielded 425 grams of tubers per plant in 1946, but only 137 grams per plant in 1945. Similar increases were obtained with the controls and with the samples treated with indolebutyric acids. The hormone treatments had little effect on the

TABLE II

EFFECT OF INDOLEACETIC ACID AND INDOLEBUTYRIC ACID TREATMENTS ON YIELD AND STARCH CONTENT OF POTATO TUBERS IN 1945 AND 1946

TREATMENT	YIELD OF TUBERS PER PLANT, GRAMS (FRESH BASIS)		STARCH CONTENT OF TUBERS, PER CENT. (DRY BASIS)	
	1945	1946	1945	1946
None	165	560	55	69
Indoleacetic acid, 63 p.p.m.	137	425	52	69
Indolebutyric acid, 63 p.p.m.	146	289	53	68

starch contents of the resulting tubers. The average starch content (dry basis) increased from 53 per cent. in 1945 to 69 per cent. in 1946.

STARCH GRANULE SIZE

Table III shows a typical distribution of starch granule sizes. The starch was separated from potatoes grown from untreated seed pieces in 1946. Measurements were made of the greatest dimension or diameter of the granules. The distribution was recorded at 4- (or 5-) micron intervals. The first column of the table lists, to the nearest integer, the midpoint of the intervals, D_i. The second column gives the fraction of the granules in each interval, f_i. The third column tabulates values of the product, $f_i D_i$. The sum of these is the granule diameter averaged for the number of granules measured, the "number-average" granule diameter, $\bar{D}_n = \Sigma f_i D_i$. For this starch preparation, $\bar{D}_n$ was 16.7 microns. When summed, the fourth column gives the "weight-average" granule diameter, $\bar{D}_w$, or the diameter of the granule of average weight. $\bar{D}_w = \Sigma w_i D_i$, where $w_i = \frac{f_i D_i^3}{\Sigma f_i D_i^3}$ is the weight fraction of granules whose diameter is D_i. $\bar{D}_w$ is perhaps a more useful measure of granule size than $\bar{D}_n$, since $\bar{D}_w$ emphasizes the few large granules which contribute most of the weight of the starch. $\bar{D}_w$ for this starch was 42.5 microns.

Approximately 50 per cent. of the granules were 12 microns or less in diameter. The paucity of similarly small granules in the potato starches measured by RIPPERTON (14), MEISS *et al.* (12) and BARHAM *et al.* (1) is attributable to the loss of small granules during the starch recovery process. The fourth column of table III shows how little the small granule fraction contributes to the average weight of the granule.

TABLE III

GRANULE SIZE DISTRIBUTION IN STARCH FROM UNTREATED GREEN MOUNTAIN POTATOES GROWN FOR 19 WEEKS IN 1946

MEDIAN GRANULE DIAMETER, D_i (MICRONS)	FRACTION OF GRANULES IN EACH DIAMETER INTERVAL, $f_i = \frac{n_i}{\Sigma n_i}$ (PER CENT.)	f_iD_i	w_iD_i
4	9.3	0.37	0
8	22.1	1.77	0.06
12	20.4	2.45	0.31
16	15.1	2.42	0.74
20	10.9	2.18	1.28
24	5.8	1.39	1.42
29	5.7	1.65	2.99
33	3.8	1.25	3.33
37	2.1	0.78	2.89
41	1.1	0.45	2.30
45	0.9	0.41	2.70
49	0.6	0.29	2.55
53	0.7	0.37	4.08
57	0.6	0.34	4.67
61	0.5	0.31	5.12
65	.....	.....	.....
69	0.1	.07	1.66
73	.....	.....	.....
78	0.1	.08	2.62
82	.....	.....	.....
86	0.1	.09	3.83
		$\overline{D}_n$ = 16.66 microns[1]	$\overline{D}_w$ = 42.54 microns[2]

[1] $\overline{D}_n$ = number-average granule diameter = Σf_iD_i

[2] $\overline{D}_w$ = weight-average granule diameter = Σw_iD_i; $w_i = \frac{f_iD_i^3}{\Sigma f_iD_i^3}$

The data of table IV indicate that treatment of potato seed pieces with the phytohormones did not materially alter the size of the starch granules subsequently produced. For example in 1946 the weight-average diameters of the granules from plants produced by untreated seed, by seed treated with indoleacetic acid and by those treated with indolebutyric acid were 43, 42, and 44 microns, respectively. Similarly, in 1945 the weight-average diameters of the granules from plants produced by untreated seed and by seed treated with indolebutyric acid and grown for 17 weeks were 35

and 34 microns, respectively. The size of the starch granule was related, in general, to the size and probably to the age of the tuber producing the granules. In 1945 the smallest granules (weight-average granule diameter 19 microns) were obtained from the smallest and youngest tubers (from plants produced by seed treated with indolebutyric acid and grown for 15 weeks). Small granules were obtained also from embryonic tubers produced by untreated seed. The largest granules from the 1945 experiments originated in the largest tubers of full maturity (170 grams average weight).

TABLE IV

EFFECT OF INDOLEACETIC AND INDOLEBUTYRIC ACID TREATMENT OF GREEN MOUNTAIN SEED POTATOES ON SIZE OF STARCH GRANULES IN THE OFFSPRING TUBERS

SEASON	TREATMENT	PERIOD OF GROWTH, WEEKS	AVERAGE WEIGHT OF TUBER IN SAMPLE TAKEN, GRAMS	WEIGHT-AVERAGE GRANULE DIAMETER, MICRONS	NUMBER-AVERAGE GRANULE DIAMETER, MICRONS
1945	None	15	†1.3	24	13
	"	15	62	35	13
	"	16	25	36	15
	"	17	147	35	15
	"	18	126	35	16
	"	19	129	38	16
	"	20	170	43	17
	"	20	112	40	16
	Indolebutyric acid*	15	†0.7	19	11
	" "	16	33	32	15
	" "	17	142	34	15
	" "	18	132	38	15
	" "	19	94	35	16
	" "	20	95	37	17
	Indoleacetic acid*	20	105	39	15
1946	None	19	approx. 140	43	17
	Indolebutyric acid*	19	" 140	44	17
	Indoleacetic acid*	19	" 140	42	17

* Concentration was 63 p.p.m.
† These tubers were selected especially for their small size.

However, no direct data were obtained concerning the relationship between age and size of tubers, and there were some cases in which comparatively small tubers produced disproportionately large granules. BARHAM *et al.* (1) found that a late harvest of potatoes, in contrast with an early harvest, decreased the average granule size in two varieties, but increased the average granule size in a third variety. BICE *et al.* (2) reported that starch granule size of wheat increased markedly up to 12 to 15 days after pollination, then remained relatively constant.

Since no difference in granule size between starches from untreated and hormone-treated potato seed pieces was found, no other properties of the starches were measured.

Summary

Treatment of Green Mountain seed potatoes with 63 p.p.m. of either indoleacetic acid or indolebutyric acid had almost no effect on the size of the starch granules in the offspring tubers. This is contrary to Zika's report for other varieties. The hormone treatment delayed germination and decreased the yield of tubers during both a favorable and an unfavorable growing season. Very small and young tubers contained predominantly small starch granules; growth of the tubers was accompanied by an increase in average granule size.

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LITERATURE CITED

1. BARHAM, H. N., WAGONER, J. A., WILLIAMS, B. M., and REED, G. N. A comparison of the viscosity and certain microscopical properties of some Kansas starches. J. Agr. Res. **68**: 331–45. 1944.
2. BICE, C. W., MACMASTERS, M. M., and HILBERT, G. E. Wheat starch properties in relation to grain maturity. Cereal Chem. **22**: 463–476. 1945.
3. DAINES, R. H., and CAMPBELL, J. C. Potato sprouting inhibited by the use of alpha-naphthalene acetic methyl ester. Amer. Potato Jour. **23**: 88–91. 1946.
4. DENNY, F. E., GUTHRIE, J. D., and THORNTON, N. C. Effect of the vapor of the methyl ester of alpha naphthaleneacetic acid on the sprouting and sugar content of potato tubers. Contrib. Boyce Thompson Inst. **12**: 253–268. 1942.
5. ————. Further tests of the use of the methyl ester of alpha-naphthaleneacetic acid for inhibiting the sprouting of potato tubers. Contrib. Boyce Thompson Inst. **14**: 15–20. 1945.
6. EYNON, L., and LANE, J. H. Starch: Its Chemistry, Technology and Uses. P. 136. W. Heffer and Sons, Ltd., Cambridge, 1928.
7. GUTHRIE, J. D. Effect of ethylene thiocyanohydrin, ethyl carbylamine, and indoleacetic acid on the sprouting of potato tubers. Contrib. Boyce Thompson Inst. **9**: 265–272. 1938.
8. ————. Inducing dormancy in potato tubers with potassium naphthaleneacetate and breaking it with ethylene chlorohydrin. Science **88**: 86. 1938.
9. ————. Control of bud growth and initiation of roots at the cut surface of potato tubers with growth-regulating substances. Contrib. Boyce Thompson Inst. **11**: 29–53. 1939.
10. LOMBARD, P. M., BROWN, B. E., and DYKSTRA, T. P. Potato production in the Northeastern and North Central States. U. S. Dept. Agr. Farmers' Bulletin No. 1958. 1944.

11. MALCHER, J., and ZIKA, M. Versuche mit Pflanzenhormonen in Bezug auf die Brennerei- und Starkeindustrie. Zeitschr. Spiritusind. **66**: No. 9/10, 2–4, No. 11/12, 2–4. 1943.
12. MEISS, P. E., TREADWAY, R. H., and SMITH, L. T. White potato starches. Ind. Eng. Chem. **36**: 159–163. 1944.
13. PUJALS, E. A., NYLUND, R. E., and KRANTZ, F. A. The influence of sprout-inhibiting and sprout-inducing treatments on the growth and yields of potatoes. Amer. Potato Jour. **24**: 47–56. 1947.
14. RIPPERTON, J. C. Physicochemical properties of edible-canna and potato starches. Hawaii Agr. Expt. Sta. Bulletin No. 63. 1931.
15. THOMAS, J. E., and RIKER, A. J. Sprouting of potatoes inhibited by plant hormones. Amer. Potato Jour. **22**: 104–113. 1945.
16. TRNKA, R., FRANTEK, V. I., and PRASKAC, L. Hormonisation und Dungung mit Handelsdungern. III. Sbornik ceske Akad. Zemedelske **17**: 214–221. 1942. (Chem. Zentr. 1944. 11, 1106.)
17. VAN DER WAAL, G. A. Bewaring van aardappelen in de praktijk. Landbouwkund. Tijdschr. **59**: 165–169. 1947. (Chem. Abs. **42**: 3100.)
18. ZIKA, M. Uber die Beeinflussung der Starkekorngrosse bei *Solanum tuberosum* durch B-Indolylessigsaure. Planta **30**: 151–159. 1939.